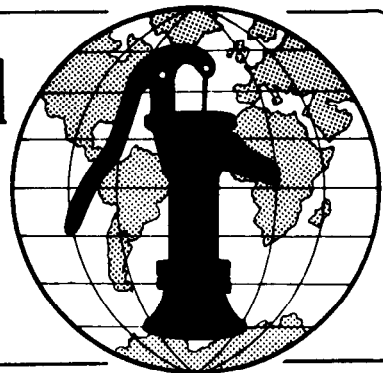


Water for the World



Designing a Landfill

Technical Note No. SAN. 3.D.1

A landfill is a means of disposing of solid waste by burying it. Designing a landfill involves calculating the amount of waste to be disposed of, determining the type of landfill, selecting a site, selecting a method of landfilling, calculating the required area of the landfill, and determining personnel and equipment required for operation. The products of the design process are: (1) a location map, (2) design drawings of the landfill, and (3) a detailed materials list. These products will be given to the construction supervisor prior to operation.

This technical note describes how to design a landfill and arrive at the essential end-products. Read the entire technical note before beginning the design process.

Calculating Waste Generation

The amount of waste to be disposed of will indicate the type of landfill to be designed and its size. The waste amount for at least five years should be calculated and the landfill designed for that length of time. The amount of waste in cubic meters equals the daily generation of waste in liters times 365 days per year, times five or more years, times a compaction factor of 0.5, divided by 1000 liters per cubic meter. The 0.5 compaction factor is an estimate of the natural shrinkage or reduction in volume that occurs to solid waste in a landfill over a period of months. This can be doubled by manual compaction or tripled by compaction with vehicles or sleds.

For example, suppose a household disposes of approximately 5 liters of solid waste per day. Then the amount of waste disposed of in five years equals $(5 \text{ liters}) \times (365 \text{ days/year}) \times (5 \text{ years}) \times (0.5) = 4.56\text{m}^3$
 $\frac{\quad}{1000 \text{ liters/m}^3}$

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To draw a location map.

Useful Definitions

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) substance such as leachate or bacteria from animal manure.

GARBAGE - Food and crop wastes from growing, harvesting, storing, preparing, cooking, or serving of food; these materials rot quite quickly.

GROUNDWATER LEVEL - The level to which subsurface water rises during any given time of year.

LEACHATE - A liquid formed when rain, surface water, or ground water passes through a landfill and accumulates dissolved and suspended matter and organic wastes; leachate can contaminate water supplies.

RUBBISH - All materials other than garbage that is thrown away, including broken dishes, utensils, and furniture; useless scraps of wood, metal, or glass, sweepings from house, yard, or street; and anything else that is discarded.

SOLID WASTE - Garbage, rubbish, animal manure, dead animals, and ashes.

A landfill serving that one family must be designed to contain 4.56m^3 . See Worksheet A, Lines 1-4.

Worksheet A. Calculating Amount of Solid Waste and Size of Landfill

Household Solid Waste

1. Daily amount of solid waste per household = 5 liters
2. Lifetime of landfill = 5 years
3. Compaction factor = 0.5
4. Total amount of waste =
$$\frac{\text{Line 1} \times 365 \text{ days/year} \times \text{Line 2} \times \text{Line 3}}{1000 \text{ liters/cubic meter}}$$

$$\frac{(\underline{5} \text{ liters/day}) \times (365 \text{ days/year}) \times (\underline{5} \text{ years}) \times 0.5}{1000 \text{ liters/m}^3} = \underline{4.56} \text{ m}^3$$

Community Solid Waste

5. Daily amount of solid waste from marketplace (or total number of households) = 400 liters
6. Lifetime of landfill = 5 years
7. Compaction factor = 0.5
8. Total amount of waste =
$$\frac{\text{Line 5} \times 365 \text{ days/year} \times \text{Line 6} \times \text{Line 7}}{1000 \text{ liters/cubic meter}}$$

$$\frac{(\underline{400} \text{ liters/day}) \times (365 \text{ days/year}) \times (\underline{5} \text{ years}) \times 0.5}{1000 \text{ liters/m}^3} = \underline{365} \text{ m}^3$$

Size of Trench

9. Depth of trench = 0.6 m
10. Area of trench =
$$\frac{\text{Line 4}}{\text{Line 9}} = \frac{(\underline{4.56} \text{ m}^3)}{(\underline{0.6} \text{ m})} = \underline{7.6} \text{ m}^2$$
11. Width of trench = 1.0 m
12. Length of trench =
$$\frac{\text{Line 10}}{\text{Line 11}} = \frac{(\underline{7.6} \text{ m}^2)}{(\underline{1.0} \text{ m})} = \underline{7.6} \text{ m}$$

Size of Area Landfill or Mound Landfill

13. Depth of depression or height of mound = 2.0 m
14. Area of landfill =
$$\frac{\text{Line 8}}{\text{Line 13}} = \frac{(\underline{365} \text{ m}^3)}{(\underline{2.0} \text{ m})} = \underline{182.5} \text{ m}^2$$
15. Width of landfill = 10.0 m
16. Length of landfill =
$$\frac{\text{Line 14}}{\text{Line 15}} = \frac{(\underline{182.5} \text{ m}^2)}{(\underline{10.0} \text{ m})} = \underline{18.25} \text{ m}$$

Another example: suppose a community marketplace must dispose of approximately 400 liters of garbage each day. Then the amount disposed of in five years equals $(400 \text{ liters}) \times (365 \text{ days/year}) \times (5 \text{ years}) \times (0.5) =$

$$\frac{\quad}{1000 \text{ liters/m}^3}$$

365.0m³

A landfill serving the marketplace must be designed to contain at least 365m³. See Worksheet A, Lines 5-8. This figure will be reduced by manual or mechanical compaction before the waste is covered with soil.

Determining Type of Landfill

The three basic types of landfills are: (1) on-lot landfills for household use, (2) community landfills used and operated by a number of households, and (3) community landfills operated by paid workers. The type of landfill selected is a matter of judgment rather than computation. The selection depends on the amount of solid waste generated, the available area on the lot, and the economics of the community. In general, Table 1 can be used to determine the type of landfill.

Table 1. Landfill Factors

Landfill Type	Determining Factors
On-lot; household use	Small amounts of waste; suitable on-lot site
Community; operated by householders	Larger amounts of waste or no suitable on-lot site
Community; operated by paid workers	Large amounts of waste and money to pay workers

Selecting a Site

The site for a landfill must meet the following requirements:

Distance. A landfill must be far enough from wells and streams to protect water supplies from contamination, far enough from dwellings to prevent causing a nuisance, and close enough to the source of the waste to avoid excessive hauling.

An on-lot landfill should be:

at least 30m, preferably downhill,
from wells and streams,
20-200m from the household.

A community landfill should be:

at least 200m, preferably downhill,
from wells and streams,
at least 200m from the nearest
dwelling,

no more than 30 minutes travel from
the source of waste (2-15 kilometers,
depending on the method of
transportation; see "Designing a
Solid Waste Collection System,"
SAN.3.D.3).

Geography. A landfill should not be located on valuable land such as crop land. It should not be located on creviced rock because of the danger of groundwater contamination, or on marshy or wet ground because of the probable production of foul odors. Try to locate the landfill downwind from dwellings. It should be near a road for easy access.

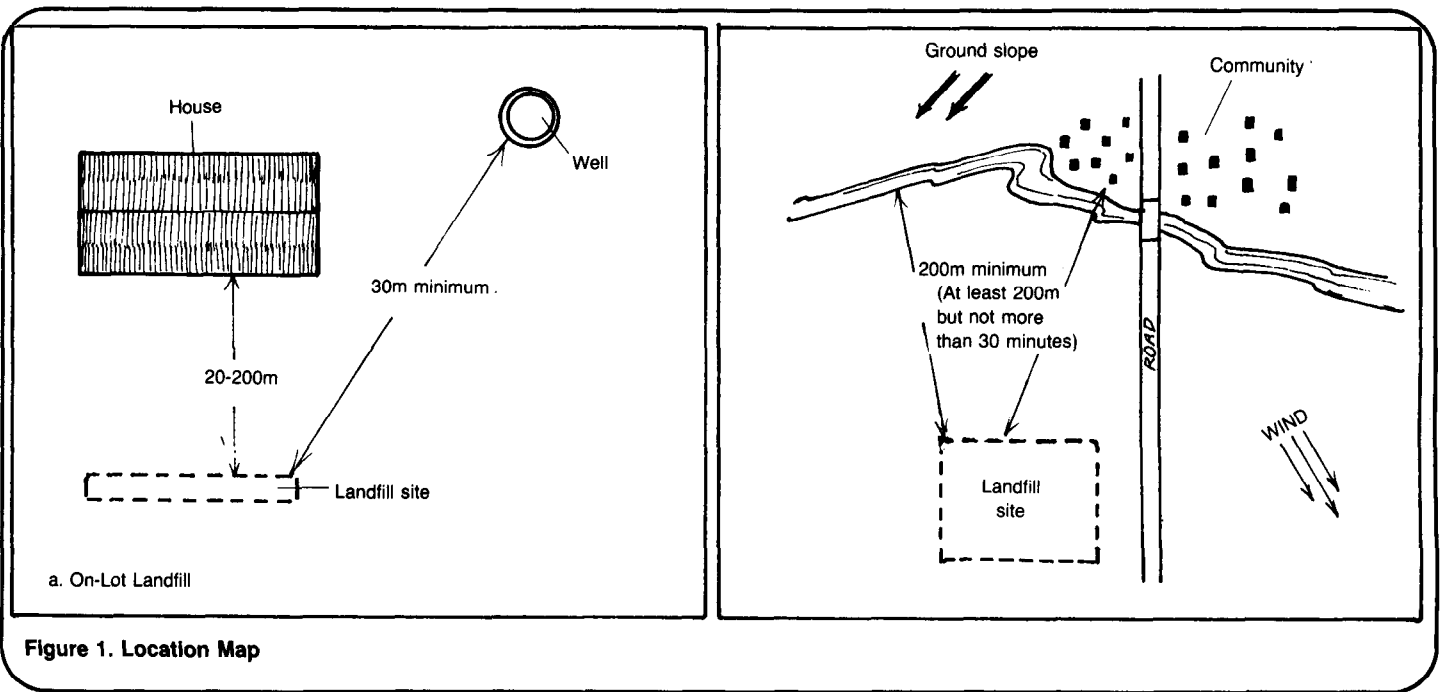
Ground Water. The bottom of the landfill must be at least 1.0m above the highest groundwater levels. Information on groundwater levels may be available from local residents, water well owners, or water well drillers. If not, a test hole 1.0m deeper than the bottom of the proposed landfill must be dug during the wettest season. If no ground water is observed in the hole, the site is suitable.

Cover soil. The landfill must be located on or near ground which is easily excavated in order to provide adequate cover material. Loamy soils, sandy loams, and permeable clay mixtures are good. Heavy, non-permeable clays are hard to work and crack when dry surfaces are exposed.

Area. The site must be large enough to accommodate the landfill. The area required depends on the amount of waste and the method of landfilling. See the section on "Calculating the Size."

Ownership. If a community landfill located on privately-owned land is being designed, written permission to use the land must be obtained from the owner. The agreement should specify the number of years of use, limits on future use and responsibility for maintenance.

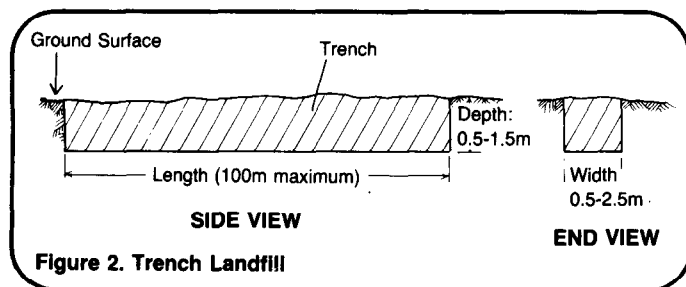
If any of these requirements are not met, another site must be found. This may require hauling wastes greater distances. When a suitable site has been located, draw a map similar to Figure 1 showing the site in relation to dwellings, water wells, streams, roads, and so on, and indicating ground slope and prevailing wind direction. Give the map to the construction supervisor.



Selecting the Method of Landfilling

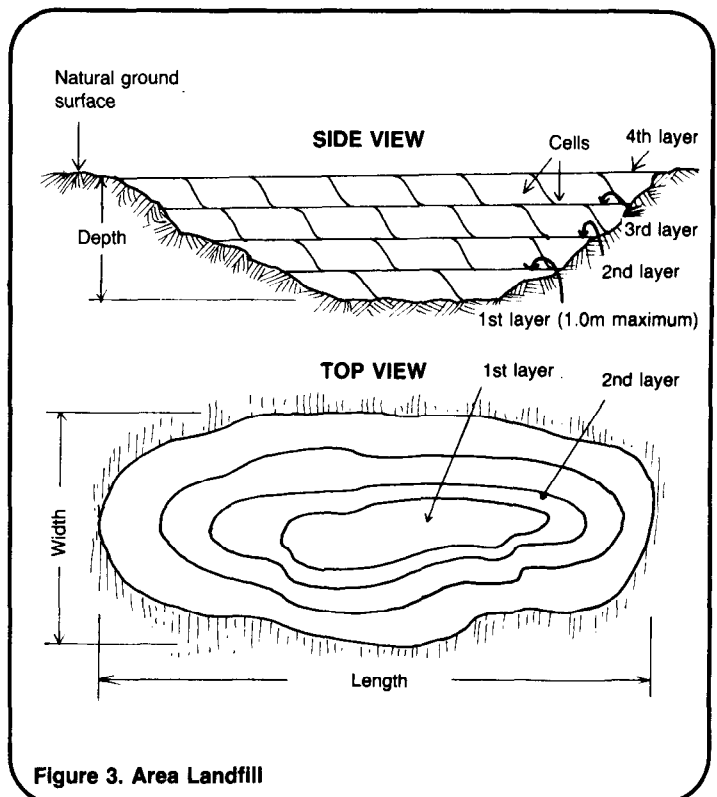
The three basic methods of landfilling are: (1) trench method, (2) area method, and (3) mound method.

The trench method involves excavating a trench, placing solid waste in the excavation, compacting it, and covering the waste with the excavated soil. Generally, only a portion of the trench is dug and filled with waste each day or week. The size of the trench will vary depending on the amount of waste to be disposed of and the equipment used for excavation. Trenches are generally 0.5-2.5m wide, 0.5-1.5m deep, and up to 100m long. The trench method is used where the ground is fairly flat or gently sloped and the soil on the site is easily excavated. See Figure 2.

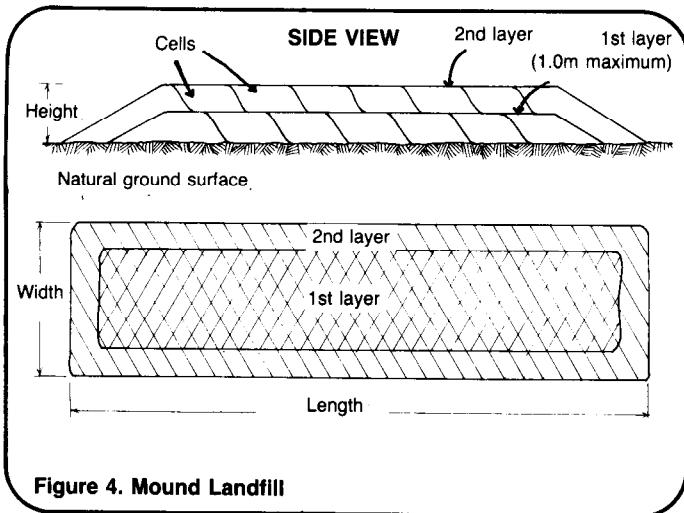


The area method involves raising a natural depression or low area by placing solid waste in the depression, compacting it, and covering it with

soil. Cover soil can be hauled from off-site or scraped from the bottom of the depression before waste material is placed in it. Although there are no design limitations to this type of landfill, waste is placed in strips or layers no higher than 1.0m. Each strip or layer may be composed of smaller sections called cells. See Figure 3.



The mound method involves placing solid waste in strips or layers no higher than 1.0m on top of relatively flat, hard ground and covering it with soil hauled from off-site. This method is generally used in areas difficult to excavate. There is no design limitation on landfill size. See Figure 4.



For example, suppose the five year accumulation of solid waste for a household, taking into account the minimum 0.5 compaction factor, is calculated to be 4.56m^3 , and that a trench method is selected with a trench depth of 0.6m. Then the area required equals 4.56m^3 divided by $0.6\text{m} = \frac{4.56\text{m}^3}{0.6\text{m}} = 7.6\text{m}^2$. The length of the trench equals the area divided by the width. If the width is 1.0m, the length equals $\frac{7.6\text{m}^2}{1.0\text{m}} = 7.6\text{m}$. Therefore, the household could dispose of its solid waste for five years in a trench 1.0m wide, 0.6m deep, and 7.6m long. See Worksheet A, Lines 9-12. Compaction will increase the useful life of the trench by one-third to one-half.

Another example: suppose a community marketplace or a number of households must dispose of 365m^3 of solid waste over the next five years, and the method of disposal is filling a natural depression 2.0m deep or building a mound 2.0m high. The area required equals 365m^3 divided by 2.0m, or $\frac{365\text{m}^3}{2.0\text{m}} = 182.5\text{m}^2$. The finished landfill will cover at least 182.5m^2 . There are a number of configurations that meet this requirement: a rectangular landfill 10.0m wide and 18.25m long, or a square landfill 13.5m on each side. See Worksheet A, Lines 13-16. Again, compaction will reduce the size of landfill needed.

When the type, method, and size of the landfill have been determined, make drawings similar to one or more of Figures 2, 3, and 4 showing the shape and dimensions of the landfill. Give the drawings to the construction supervisor.

Determining Equipment and Personnel

The equipment and personnel needed to operate a landfill depend on the size of the operation, the ease with which cover soil can be excavated, and the work habits of the community. There is no specific means to calculate these factors. An on-lot landfill may require only a shovel and someone to dig. A community landfill, whether operated by household members or paid workers, may require a number of

Table 2 indicates which landfilling method may be most suitable for certain site conditions.

Table 2. Landfill Method and Site Conditions

Landfill Method	Site Conditions
Trench	Fairly flat or gently sloped; easily excavated
Area	Natural depression or low area; cover soil on-site or within suitable hauling distance
Mound	Relatively flat, high ground water and difficult to excavate; cover soil within suitable hauling distance

Calculating the Size

The area required for a landfill equals the amount of solid waste to be disposed of over a certain period of time, perhaps five years, divided by the depth or height of the completed fill.